AN EXPERIMENTAL EXAMINATION OF THE PHENOMENA USUALLY ATTRIBUTED TO FLUCTUATION OF ATTENTION.[1]

By C. E. FERREE, A. M., M. S.

TABLE OF CONTENTS.

[1]From the Psychological Laboratory of Cornell University.

INTRODUCTION.

It is commonly admitted by experimental psychologists that no final explanation has as yet been offered of those fluctuations of minimal stimuli and minimal stimulus-differences which go by the general name of 'fluctuations of attention.' We have peripheral theories and central theories and mixed, peripheral-central theories; and, without doubt, we have a good deal of scattered knowledge about the conditions which underlie the phenomena in certain of the fields of sense. But this chapter of psychology is, on the whole, still open. G. E. Müller, for instance, writes in 1904 that "zu feststehenden Resultaten von allgemeiner Bedeutung haben indessen diese Untersuchungen, die sich in ihren Ergebnissen und Schlussfolgerungen vielfach wiedersprechen, bisher noch nicht geführt." [1] Unless one is prejudiced in favor of some particular theory, one cannot but subscribe to this opinion.

Considerations of this sort led us to begin a systematic investigation of the subject which has extended from the winter of 1903 to the present time. Cutaneous and visual stimuli were used; but, since the former gave uniformly negative results, it has been possible to confine our attention almost exclusively to the latter. We had hoped, likewise, to include auditory stimuli in this series of investigations, but circumstances have rendered it necessary that we make them the subject of future study.

It has become evident in the course of the work that a complete account of the fluctuation of visual stimuli must take into consideration also the fluctuation of the negative after-image. The results of this investigation will be made the subject of a second article, to be followed by a third in which the conclusions of the two preceding articles will be considered from the standpoint of theory and in the light of preceding work. The present study is a reproduction, with some changes, of a paper read before a meeting of experimental psychologists held at Cornell University in March, 1904. It has seemed advisable to publish it in its present form, rather than to wait for a more complete treatment, as was originally planned, because of the evident revival of interest in the problem and the appearance of the recent papers of Dunlap,[2] Killen,[3] and Hammer.[4]

For the sake of clearness, the following order of presentation will be adhered to as closely as possible:

---

[1] Die Gesichtspunkte und die Tatsachen der psychophysischen Methodik, 1904, 110.

[2] K. Dunlap: Psychol. Rev., XI, 308.

[3] B. Killen: this *Journal*, XV, 512.

[4] B. Hammer: Zeits. f. Psych., XXXVII, 363; *cf.* C. E. Seashore, *ibid.*, XXXIX, 668.

1st. A statement of theory sufficiently comprehensive to render the results intelligible in terms of it.

2nd. A statement of the lines of investigation.

3d. A statement of results in general.

4th. A statement of results in detail.

I. Visual Stimuli.

(i) *Statement of Theory.* It is our purpose to show in this paper that the intermittences of sensation resulting from minimal visual stimuli which have been referred for explantion to fluctuation of attention are, in reality, simply adaptation phenomena somewhat obscured by the special conditions.

Adaptation is, in itself, a continuous phenomenon, but its continuity is interfered with by eye-movement,[1] blinking, etc. Through these influences, probably essentially through that of eye-movement alone, it becomes an intermittent process, whether the stimulus be liminal or intensive, provided that proper areas be used. The conditions are especially favorable for short periods of intermittence when the stimuli are liminal and of small area.

Eye-movement tends to delay adaptation when the stimulus is liminal and of small area. When the stimulus is much above the limen and the area very small, complete adaptation is prevented, because, under these conditions, no one part of the retina is stimulated long enough to produce the required physiological effect. Also, under such conditions, it is of very short duration, when attained, because a slight shift of the retina is sufficient to produce a complete change in the area stimulated and thus to afford the adapted elements the relief necessary to the revival of sensation. When, on the contrary, the area is very large, these relatively small eye-movements do very little towards relieving the part of the retina stimulated; consequently, complete adaptation takes place much more quickly, and persists apparently indefinitely, unless relief be similarly afforded by some other agency. Areas ranging from 2 mm. to 3-4 cm., viewed at a distance of 1 meter or more, are especially favorable for short periods of intermittence; hence, in the previous investigation of this phenomenon, it is only natural that they should have been chosen and the remainder overlooked.

In all experimental work, however, the conditions that are unfavorable to the production of the phenomenon are as im-

[1] While working with after-images, this past year, we chanced upon another factor in adaptation, which (so far as we can at present tell) promises to be important. Just how much it bears upon the fluctuation of minimal visual stimuli cannot now be stated. We hope, however, to discuss it fully in the article on the fluctuation of after-images.

portant as, and often more important, for theory, than those more favorable. This proves to be true in the case of what are commonly called 'fluctuations of attention.'

Our plan of experimentation, in general, has been to isolate, and test out separately, the probable factors involved, central and peripheral, endeavoring so to vary the conditions as to relieve introspection of any undue burden of analysis. Where the possible factors are numerous and complex, introspective analysis unaided can scarcely be relied upon to solve the problem.

(ii) *Lines of proof.* It is proposed to show:

(1) That involuntary changes in accommodation are not essential factors in the phenomenon. (2) That a stimulus which is not, in itself, intermittent, acting upon the optic centre, does not produce an intermittent sensation. (3) That all liminal stimuli do not fluctuate. (4) That adaptation is an intermittent process under the conditions holding for fluctuation. (5) That adaptation and fluctuation are identical. (6) That adaptation is intermittent chiefly because of eye-movement. (7) That the same correspondence between adaptation and fluctuation obtains in indirect vision.

(iii) *Results: General.* We have the following results to offer at this stage of the work.

A. Involuntary changes of accommodation are not essential.

Aphakial subjects experience these fluctuations with apparently no greater variation of phase than can be accounted for on the ground of normal individual differences. Hence, we can conclude that involuntary changes of accommodation play no essential part in the phenomenon.

B. A non-intermittent stimulus produces a continuous sensation.

A minimal and continuous light sensation, produced by electrical stimulation of the cerebro-retinal mechanism, does not fluctuate. Here is a liminal stimulus capable of affecting the optic centre, and pouring in upon it, the effect of which gradually dies out, but shows no signs of intermittence. This fact would seem to indicate that we must look to the periphery for an explanation of fluctuation; for if it were conditioned by central factors, it would be difficult to see why an exception should be made in this case, which is distinctive only in that certain of the peripheral factors which usually modify retinal stimulation are omitted.

C. Not all liminal stimuli fluctuate.

Liminal visual stimuli of large area, also certain combinations

of stimulus and background with very small areas, do not fluctuate.

D. Adaptation is an intermittent process under the conditions holding for fluctuation.

Adaptation, in general, with areas equal to those with which fluctuations are obtained, is a periodic phenomenon, no matter what the intensity of the stimulus used. The condition of a just perceptible difference between the stimulus and background is favorable, but is by no means essential to the phenomenon. Any stimulus that will completely adapt into its background will do so intermittently within this range of areas; while a stimulus whose qualitative relation to its background is such that it will not disappear completely shows periodic increase and decrease in intensity.

E. Adaptation and fluctuation are identical.

Whatever conditions relative to the stimulus, or to the combination of stimulus and background, affect the adaptation time, produce a similar effect on the fluctuation time; the effect showing itself either in the phase of visibility, or in the phases of both visibility and invisibility.

Some of the ways by which this correspondence was shown are:

(a) *Fading of the stimulus into its proper gray during the course of a single fluctuation.* In the course of a single fluctuation a colored stimulus is observed to fade into a gray, of a shade depending upon the color used, as always happens in complete color adaptation. Further, the times required for the several colors to fade sustain a very definite relation to their adaptation times. In order of their value from least to greatest, they are (for our stimuli) red, green, blue and yellow. There is little difference, however, in the times required for the disappearance of the residual grays in each case. Moreover, such differences as do occur are chance variations, as is shown by the following averages: red, 1.65 sec.; green, 1.97 sec.; blue, 1.61 sec.; yellow, 1.65 sec. Thus it would seem that the difference in the phases of visibility for these four colors, which is the phenomenon discussed in the next section, does not depend upon their respective brightnesses, but is a duration peculiarity of the processes themselves.[1]

[1] This point is of two-fold importance. (1) It suggests that the adaptation time of a color is not a function of its brightness; *i. e.*, yellow and red have in no wise different adaptation times because of their positions in the white-black series. (2) It shows that the different visibilities in the fluctuation experiments are not conditioned by the relation of the brightnesses or proper grays of the colors used to the background, but are true expressions of characteristic differences in the color processes themselves.

(b) *Comparison of fluctuation times with adaptation times for colors and grays.* Colors and grays were found to have an order of fluctuation times corresponding to their adaptation times. Four colors, red, green, blue and yellow, gave very different fluctuation periods as compared with each other and with no. 27 Hering gray. The visibility times obtained were in the following order: red, green, blue and yellow, the yellow being nearly four times as long as the red. The complete adaptation times for sheets of the same colors were found to have the same order of length and a rough correspondence as to ratio of length. Further, a striking fact came out with regard to the phases of invisibility. Since red, for example, has a shorter phase of visibility than green, one might naturally expect that its phase of invisibility would also be shorter than the invisibility time of green. The reverse, however, is true. Red has a longer invisibility than green, and this peculiarity is especially marked if one considers the proportionality between the phases, *i. e.*, the ratio invisibility: visibility. The same thing is true of the complementaries blue and yellow. Clearly, we cannot look for a central explanation of this peculiarity; but it seems just what we might expect of adaptation from the standpoint of the compensation theory. The recovery process for the red is the green process. The green process is longer and seemingly more tenacious than the red, as is shown by the adaptation experiments proper, and is further borne out by the longer duration of the green after-image. A similar relation obtains in the blue-yellow process. We have now in progress a series of experiments that will enable us to make an exact comparison of the recovery times for these four colors.

(c) *Combinations of stimulus and background that influence adaptation times correspondingly influence fluctuation times.* By keeping the background constant and varying the stimulus, or conversely, by keeping the stimulus constant and varying the background, a difference in the period of fluctuation was obtained, showing itself chiefly in the phase of visibility. This same thing held in the recognized adaptation experiments. The variations of the phases of visibility and invisibility that were produced in the adaptation experiments were produced also in the fluctuation experiments, the only departure from precise correspondence being that the differences were more marked in the former case, as would be expected from the longer duration of the process.

(d) *Method of areas.* By adequate variation of the area of the stimulus, the phase of visibility was varied from quite long with small areas to nearly zero with large, while the phase of invisibility ranged from very short with small areas, to approximate infinity with large areas, *i. e.*, the faded-out stimu-

lus did not reappear. Thus the phases of visibility and invisibility are, inversely to each other, functions of the stimulus area. The curve representing the phase of visibility starts high on the ordinate and drops down fairly regularly to near the abscissa; while the curve representing the phase of invisibility starts near the abscissa and rises to infinity. The areas chosen do not make the phase of visibility infinite with liminal stimuli; but it is presumable that an area small enough to do this might be found. The curve representing the total period begins high on the ordinate, bends down towards the abscissa, rises again, and passes to infinity. A similar effect, much more marked, was obtained in the adaptation experiments. With the smallest areas used above, the spot never disappeared. Thus the curve representing the whole period starts at infinity, bends down, but not so near to the abscissa as before, rises again, and passes back, but much more irregularly, to infinity. Further, if we took areas sufficiently large, not only did the faded-out stimulus not become visible again under the conditions of fixation observed in such experiments, but it refused to reappear with quite extensive voluntary eye-movements.

Now there seems no way of explaining these results from any peculiarity of function in the centre. In the case of liminal stimuli, the intensities were chosen subjectively equal, consequently there could be no reason for a central discrimination, on the ground of intensity, adequate to account for the wide range of variation obtained; and as for the adaptation experiments, a very flood of vaso-motor waves,[1] etc., would scarcely suffice to wipe out stimuli of so great intensity. If it be argued that it is not fair to attempt to carry over this explanation to the adaptation experiments, we must reply that there would remain, then, the very great difficulty of explaining the close correspondence in the results obtained in the two series of experiments, if entirely different causes were ascribed to the two sets of phenomena. In favor of physiological rhythm, it might be said, however, that there seems a bare possibility of establishing a connection between it and eye-movement. But only in this way could it fit into a theory that should explain all the results cited above. Again, if from any standpoint it be argued that central factors[2] are involved in eye-movement, blinking, etc., and that these influences, therefore, make for a central theory, we reply that the movements are more likely to be reflex, made in sympathy with the changes and needs of the retina. But granted that they are central, they still play no greater part in the explanation of the phenomenon than is

[1] J. W. Slaughter: this *Journal*, XII, 313.
[2] E. A. Pace: Philos. Studien, VIII, 388; XX, 232.

the case with adaptation in general. The part played by all of these factors becomes a common problem, to be investigated in connection with adaptation, and not substituted for it as a *vera causa*. There seems, likewise, little chance of explanation of these results from the side of attention. In fact, they seem to be precisely contradictory of any theory that seeks its account from this source. Increase in area of the stimulus is presumed to be equivalent to an increase in intensity, as regards its noticeability or its efficiency [1] for attention. Efficiency, or whatever may be considered as its equivalent in these results, let the criterion be what it will, is reduced to a minimum.

F. Adaptation is rendered intermittent chiefly by eye-movement.

That eye-movement[2] is chiefly responsible for the intermittence of adaptation seems evident from the results. Blinking might enter in, as an occasional factor, to delay adaptation or cause the reappearance of the faded-out stimulus; but it is much too infrequent to explain all of the reappearances. Besides, it could offer no explanation for the difference in the times of visibility and invisibility for the different areas, since

[1] There are, probably, two factors which give an increased area an increased efficiency for attention. (1) There is an actual increase in the intensity of the sensation. For example, when our stimulus was obtained by light transmitted through opal glass, the source of light had to be moved farther away in order to give a liminal effect when the area of the stimulus diaphragm was increased. Likewise, when the stimulus was seen by reflected light, the opal glass plate had to be moved farther out from the background when the area of the stimulus was increased. (2) The increased area occupies more of the field of vision; hence the rival area is not only of less extent (fewer distracting factors, etc.), but is pushed more and more into the field of indirect vision. The first factor was ruled out by decreasing the intensity of the stimulus until it was liminal. The second, however, operated to give our large areas greater efficiency for attention. But in spite of this, the large areas, although favoring rapid adaptation, gave us minimal visibility. Besides helping to make our point for adaptation, this result serves as a striking illustration of how little the central factors avail against the peripheral in so-called sensory attention.

[2] The other factor conditioning adaptation is probably, likewise, essentially dependent upon eye-movement. At least, the modification which gives it a bearing upon this problem is caused by eye-movement. The effect produced is, similarly, a freshening of the adapted elements, and will be understood, throughout the discussion, to supplement the change produced by shifting the adapted elements into a region of different stimulation. Since its action in point of time follows immediately upon eye-movement, and does not change, but only supplements, the restoration produced by change of stimulation, there was little apparent need of it to explain the results of the following tables. Hence, had it not come to light in the work on after-images, it probably would have been entirely overlooked.

the amount of relief afforded in each case would be the same. Eye-movement alone seems adequate to do this.

That eye-movement produces its effect in the manner we have stated probably needs further proof. Hess[1] has contended that a spot once adapted-out will not reappear so long as fixation is held perfectly steady; but his experiments do not indicate how eye-movement causes reappearance. MacDougall[2] explains the effect of eye-movement upon the reappearance of minimal visual stimuli on the basis of innervation. Innervation, however, could not account for phases of invisibility ranging from nearly zero to infinity; besides which, extensive voluntary eye-movements were wholly ineffective to revive sensation in the case of the largest areas used. Similarly, the mechanical effects of pressure, etc., are ruled out. Hence we seem not only warranted, but forced, to fall back for explanation upon an actual shift of the adapted elements away from the area of stimulation.

A more direct experimental confirmation, than was afforded by the method of variation of areas, of the view that eye-movement interferes with the course of adaptation, and is also the conditioning factor for the wide range of variability found in the phases of visibility and invisibility in the fluctuation experiments, is given by the following results. An examination of the average frequency of eye-movement in the horizontal and vertical planes during fixation showed that three of our observers had a marked excess in both frequency and range in the horizontal, while the fourth had an excess of frequency in the vertical, but of range in the horizontal plane. This appeared to mean that, for three observers, there was a greater change of stimulation, and consequently greater relief for the adapted elements, in the horizontal than in the vertical direction, while the reverse was true, though probably to a less degree, for the fourth. To test this interpretation, stimuli longer than broad were used,[3] *e. g.*, slips of paper 5 mm. x 40 mm. When these were placed with the longer dimension vertical, the shorter dimension would fall in the direction of greater unsteadiness of fixation for the three observers who had the excess of eye-movement in the horizontal plane. Consequently, a maximal interference with adaptation for these stimuli would be obtained, and one might expect an increase in the phase of visibility and a decrease in the phase of invisibility. On the other hand, if the longer dimension were placed in the horizontal and the shorter in the vertical plane, a mini-

[1] C. Hess: *von Graefe's Archiv*, XL, 2, 274.
[2] W. MacDougall: *Mind*, XI, 316; XII, 289.
[3] This procedure was suggested by Professor L. Witmer, of the University of Pennsylvania.

mal interference possible to these stimuli would be secured, and a decrease in the phase of visibility and an increase in that of invisibility should ensue. For the fourth observer, with the stimulus arranged as described above, the reverse should be true; but probably not in so marked a degree, since his range was greater in the horizontal, and this fact to a certain extent counteracted the effect of frequency. This observer also had an astigmatism in the vertical plane, which caused the stimulus to become spreading and diffuse in the horizontal, a result equivalent to greater breadth for adaptation.

That these methods of arrangement of stimulus caused a marked change in the phases of visibility and invisibility for each observer will be seen by inspection of the Tables. Indeed, the correspondence between the quantities: $\frac{\text{visibility} \div \text{invisibility}}{\text{visibility}^1 \div \text{invisibility}^1}$ and $\frac{\text{frequency}}{\text{frequency}^1}$ is much closer than was anticipated.

G. Correspondence of Adaptation with Fluctuation in Indirect Vision.

To show that fluctuation in indirect vision is not a special phenomenon, but that the correspondence between adaptation and fluctuation obtains here as well as in direct vision, the following set of experiments was carried out. (1). Beginning with direct vision, a liminal stimulus was moved successively 4, 8, 12, 16, etc., cm. towards the periphery, and records were obtained at each point. A parallel set of records was obtained with the same stimulus at full intensity. Both sets of records showed a fairly regular decrease of visibility and increase of invisibility as the stimulus was moved towards the periphery. The adaptation times obtained in a separate series of experiments with the same stimulus also showed a corresponding decrease from direct vision to periphery.

(2). An increase of area with liminal stimuli in indirect vision gave a decrease of visibility and an increase of invisibility, very much the same as was obtained for direct vision.

There seems little doubt that all the results secured for direct vision could have been paralleled for indirect vision. The above series, however, satisfied us that the phenomenon here is essentially the same. It seems, then, that the conclusion is justified that adaptation causes the disappearance of the stimulus, and unsteadiness of fixation the wide range of visibility and invisibility in case of different areas, and the restoration when complete adaptation has set in; and that this effect is due to relief of adapted elements by actual shift away from the area of stimulation, or rather into a region of different stimulation.[1]

[1] Together with the supplementary factor mentioned but not specified above,—if this prove to have the efficacy which we now incline to ascribe to it.

H. FACTS OF MINOR IMPORTANCE.

The following facts of minor importance may also be cited.

(a) *Result of increasing the distance of the observer.* The effect of increasing the distance of the observer from the stimulus was tried The area subtended by the stimulus on the retina follows the law of inverse squares. Although the phase of visibility increased and the phase of invisibility decreased with the increase of the observer's distance, still the results did not at all closely follow those obtained by the corresponding variations of area observed at a distance of 1 meter. The phase of invisibility increased much more rapidly with the increase of distance than was demanded by the law of inverse squares. This seems to argue in favor of eye-movement; for the greater the observing distance, the greater is the shift of the adapted elements away from the stimulating area with each eye-movement; hence the greater is the interference with the course of adaptation.

(b) *Connection between reappearance, and conscious eye-movement and blinking.* Experiments for recording[1] the connection between reappearance and conscious eye-movement and blinking showed coincidence in from one-third to one-half the total number of cases.

(c) *Effect of moving the eyes voluntarily.* Records of series in which an observer purposely moved his eyes at short intervals showed very few fluctuations. Another observer was directed to relieve the strain when, and as, impulse directed. No fluctuations were experienced in one revolution of the drum: 102 secs.

(d) *Effect of momentary cessation of the stimulus.* Anything else that temporarily relieved the retina, such as the interposition of some object between the source of light and the screen when the spot was made visible by transmitted light, caused reappearance when the spot had vanished, and delayed disappearance when the spot was visible.

(e) *Influence of practice.* An inexperienced observer usually obtained longer times of visibility and shorter times of invisibility until a certain stage of practice was reached. Some, indeed, were unable at first to get fluctuations at all. This is precisely what would be expected as the result of unpractised fixation upon adaptation. Further, the result seems incompatible with the theory of fluctuation of attention, for one

[1] The method of recording was simple. When reappearance came with conscious eye-movement or blinking, *O* substituted for the usual release of the key an extra pressure and immediate release. With practice, this method offered little if any distraction.

would expect practice to increase, certainly not to diminish, efficiency of attention.

Again: towards the close of a sitting, with one of our observers, the phase of visibility began to lengthen and the phase of invisibility to decrease very perceptibly: in a few cases so much so, that disappearance did not come at all. At these times the observer complained of eye-fatigue and inability to fixate steadily. This result, too, testifies for adaptation and against central factors.

(f) *Introspective evidence.* Introspection also furnishes valuable evidence. For all observers the spot faded gradually,[1] and as this process went on the strain of attention increased, reaching its maximum with the disappearance of the stimulus, and continuing until reappearance, when momentary relief was experienced. The natural attitude of our observers seems to have been to hold the sensation as long as possible. Hence it was to be expected that the strain should increase with the decrease of the sensation. Had their attitude been different, had they, for instance, been instructed that disappearance was the thing to be expected and attained, it is possible that relief might have come with invisibility: that relaxation of attention might then have ensued. Even so, it would have been the result and not the cause of the disappearance. Moreover, the conditions of the experiment make for stimulation rather than for fatigue of attention. The constantly changing stimulus, the unexpected reappearances, etc., are attention-compelling to a high degree. There is no monotony. There are rather ele-

---

[1] The conflicting reports on this point in the literature have probably been due to the peculiar difficulties attending observation with the Masson disk. With stationary stimulus and background, such as were used by us, there is no doubt that the stimulus disappears gradually. If, on occasion, the actual change in intensity could not be detected, the disappearance was gradual and progressive in point of area, the background encroaching upon the stimulus from one direction or another. More will be said about this type of disappearance in a later article.

If it be contended that stimuli whose intensity can be detected in decrease are not liminal, we reply that, in practice, just noticeability is not so consistently obtained that the detection is impossible. We have worked most carefully to get this degree of intensity, approaching the point from either direction, and still the observer would report, during the course of the fluctuation, that the stimulus faded out. What holds of our stimuli has probably held also of others; for we undoubtedly succeeded in getting finer adjustments of intensity with the arrangement finally adopted than was possible with the Masson disk. With the Masson disk itself fading was recorded by our observers.

Dealing, as we did, with many degrees of intensity, facility for judging intensity changes was naturally acquired. During this time, besides, two of our observers were regularly working on the determination of visual limens.

ments of fascination. As one observer stated, "one is always on the alert to see what will happen next." In fact, were we endeavoring to demonstrate an unwavering attention, scarcely a better set of conditions could have been selected.

It will be understood here, as elsewhere in the discussion, that our contention is not that attention does not fluctuate.[1] That is a question aside. We are merely concerned with showing that certain phenomena, that have usually been attributed to fluctuation of attention and cited as its classical demonstration, are to be otherwise explained. That there is fluctuation on the content side of consciousness goes without saying: the sensation comes and goes. But we believe not only that this fluctuation is to be explained wholly by reference to the sense process, but also that the associative factors that aid in the exaltation of the sensation are all the more active because of this sinking of the content below the limen on the peripheral side. We may add then that, in so far as the facilitation of the process elevated to prominence, or the inhibition of other processes, depends upon associative factors, it should be maintained that the conditions of these experiments make for an exalted and sustained attention.

(iiii). *General description of method and apparatus.* Before going more into detail as to method and results, we may remark that all devices that did not produce decided changes of result have been considered as worthless for yielding evidence in a case where without change in the experimental conditions the variations are so considerable. One finds cited in the literature, as due to some change in method or in support of some particular theory, variations no greater than our records showed from day to day without any change in the experimental conditions. There is, in dealing with this problem, especial need for clearly cut and decisive methods of experimentation, as well as for extreme caution in referring slight changes in result to a variation of experimental conditions.

---

[1] In so far as attention is considered as a state or mode of consciousness, it may be said to fluctuate. But interpreted in this sense, it is ruled out for purposes of explanation. We must look, instead, to the processes concerned in giving this particular state or mode to consciousness. The above paragraph is written from the point of view of the central processes involved. If we are to investigate the action of these processes, it would be well to have consciousness as purely central as possible, *i. e.*, ideas should be worked with, instead of sense perceptions. The changing content given by the peripheral process is fatal to the determination whether the central processes will act continuously for any length of time in a given relation.

In general, we probably recognize too little the difference between attention where the content is peripheral, and attention where it is central. The distinction should undoubtedly be made in any discussion of fluctuation.

We have even found it necessary not to be obliged to compare results obtained at different sittings, because of the subjective changes that occurred from time to time in spite of experimental control. Our comparisons have, therefore, been planned in series to be finished at a single sitting, and the order of their presentation has been changed so as to compensate as much as possible for probable changes in the condition of the eyes and fixation-apparatus from the beginning to the close of the period. Series, then, were compared from day to day, rather than the members needed to make a single series.

For registration, throughout all of the work, a Ludwig-Baltzar kymograph was used; together with a Marey tambour and bulb, whereby the entire course of the fluctuation as well as mere appearance and disappearance could be traced, when desired; and an electromagnetic time-marker in circuit with a metronome, enclosed in a soundless box. All of this apparatus was screened from the observer by a sliding curtain. The work was done mostly in a long room, the 'reaction room,' with the windows all at one end. Thus cross-lights, unequal illumination of the background, etc., could be avoided. The observer sat with his back to a high window and his head in a head-rest fastened to the edge of a long table, along which the frame bearing the stimulation apparatus was moved as required. The time unit throughout is 1 sec.

(v) *Results.* (*In detail.*) It is scarcely necessary to mention that the results, unless otherwise stated in the tables, are averages obtained from a large number of records. In the main, throughout the work, they were confirmed not only by the writer and the observers cited: *viz.*, Misses Fitch (*F*) and George (*Ge*) and Messrs. Sabine (*S*) and Galloway (*Ga*), but also by a number of the students of the junior training course, either as a part of their regular work, or as substituted for it. Where results have not been obtained from all of the regular observers, this has been due solely to lack of time. *S* and *Ge* gave the least and *Ga* the longest time to the work. All four observers were students in the department of psychology, and had had laboratory training. *Ga* had also had experience with the problem, both as experimenter and observer, at the University of Michigan.

A. Involuntary Changes of Accommodation are not Essential.

Two aphakial subjects were experimented upon. One of them had so little accommodation that words in fine print could not be moved more than 2 mm. farther from or nearer to his point of clearest vision (determined by the focus of his glasses) without becoming less distinct. His head was clamped in a

head-rest, and the card slid along a meter rod at the level of his eyes in the median plane. Every precaution was taken to secure accuracy. It may safely be said that the man was practically without accommodation. As was stated before, the results obtained from both of these men were uniformly negative, *i. e.*, no greater variations were found than can be explained on the ground of normal individual differences.

B. A NON-INTERMITTENT STIMULUS PRODUCES A CONTINUOUS SENSATION.

The well-known fact that make or break of a direct current produces a flash of light, if the electrodes are properly applied, led us to believe that, if the current were rapidly interrupted, these flashes might be caused to fuse into a continuous sensation. This proved to be true. An interrupter so constructed that six makes and breaks occurred with every revolution of the interrupting cylinder was used. It was driven by a motor, and its speed of revolution was regulated by a transformer,[1] so finely graduated that a change of a single interruption could be obtained. In circuit with the observer and the battery was inserted a resistance rack of German silver wire, also a Westinghouse ammeter graduated in milliamperes. By this arrangement it was possible to keep the current flowing through the circuit absolutely constant. A speed indicator was also used. This was rendered necessary for the double reason that the quality of the stimulus depended upon the rate of interruption, and that any change in the rate influenced the amount of current flowing through the circuit. This latter phenomenon was probably due to induction effects in the coils of wire used. The number of Leclanché cells required to produce the stimulation was usually eight, although as few as four and as many as twelve were used for different observers. The current flowing through the circuit, when liminal effects were obtained, ranged from one to two milliamperes. The one electrode was placed in the hand and the other, a sponge electrode, above the eye on the nasal side. The observer was stationed in the

[1] The speed-transformer, made to our order, was in the form of a segment of a cone, with a grooved surface for the retention of the motor and interrupter belts. The dimensions of the segment were such that the decrease in circumference from groove to groove was very small. This arrangement, together with graduated pulleys on the motor and interrupter, made very slight changes of speed possible.

The interrupter consisted of two brass cylinders with six equal open and closed spaces on either surface. An insulating cross-section separated the two cylinders. This duplicate arrangement was not necessary, except that it made the connections more convenient for our purpose, and that, by a proper setting of the brushes, the instrument could also be used as an alternator. The motor and interrupter were mounted on sliding frames, in order that the belts might be kept taut.

dark-room, and allowed to adapt. Then the current was applied, and carefully worked down until liminal effects were produced. The sensation chosen for observation was of the nature of an irregular patch or cloud of light, varying in color for different observers through violet, blue, and yellow.

The sensation, when liminal, usually lasted about 30 seconds, gradually fading out, and in no case reappearing however long the current was applied. The effects obtained at different rates of interruption show differences. Lower rates usually produced a series of flashes, in which more or less irregular patterns were made out. A little higher rate produced bars on a colored background. With a still higher rate, the bars assumed a radial position around a dark opening fringed with colored light. Here began the transition stage. An increase now gradually changed the effect to an uniformly colored field. This fusion usually came at rates ranging from 85-100 interruptions per second. One observer at 80 saw a dark violet field; at 85, purple; at 100, blue; and from 120-162, yellow. It would be interesting to discover whether there is a definite order in the succession of colors for all observers as the rate is increased. The point being merely incidental to our purpose, the investigation was not carried far enough to determine this.

That the retina is stimulated is indicated by the following experiment. A rate of interruption was chosen that would produce bars. The observer stimulated each eye separately and noted the patterns obtained. Then the electrodes were applied above both eyes simultaneously. It so happened that the bars for one eye were inclined towards the horizontal, and for the other towards the vertical. When both eyes were stimulated at once, and the fields superposed, the two patterns still remained distinct, with the bars set obliquely to each other. As to whether the visual substance was involved, the experiment showed that there was always an after-effect, which behaved much as after-images do. However, there was rarely any trace of complementary coloring. In any event, the result goes to prove that a continuous stimulation, reaching the optic centre, does not produce an intermittent sensation.

The data of C. and D. are, for convenience, subsumed under E., to aid in showing the correspondence between adaptation and fluctuation.

C, D, E. Adaptation and Fluctuation are Identical. Correspondence is Shown by:

(a) *Fading of the stimulus into its proper gray during the course of a single fluctuation.* A Masson disk of the standard dimensions was used. The colors (Hering standard) were

red, green, blue, and yellow. The background was neutral engine-gray, darkened by 180° of velvet black.

The change into a gray differing from the background was first reported by Dr. Bentley. Better to bring out the phenomenon, a comparison ring of gray was made concentric with the colored ring. The judgment was difficult, and it has not been possible as yet to repeat the experiment under more favorable conditions. The grays into which the colors changed were judged of different brightnesses in the order, from least to greatest, of blue, red, green, and yellow. These grays correspond to those obtained when these particular colors, saturated, were adapted down.

Adaptation, then, evidently carries the colors to the limen. That it is also adequate to get rid of the gray remaining cannot be questioned. Consequently, it does not seem necessary to supply another process to complete the disappearance, especially when there is nothing in the course of the phenomenon to indicate the need of such a supplement. Introspection shows the change from start to finish to be uniform and contin-

TABLE I.[1]

Ga. Fading of a color into its proper gray during the course of a single fluctuation.

Stimulus	Number of Fluctuations	Changes to Gray	Vis. Color	Vis. Gray	Invis.	Order of Brightness of Gray
Red, 2x5 mm.	21	8	2.4	1.65	1.99	3d.
Green, " "	14	7	2.99	1.97	1.79	2d.
Blue, " "	13	7	3.57	1.61	2.04	4th.
Yell'w, " "	14	6	3.70	1.65	2.02	1st.

uous. It will be noticed that the difference between the total phase of visibility for the four colors in Table I is not nearly so great as it is in Tables II, III, IV, and V. The recovery-peculiarities characteristic of adaptation are also much less noticeable in the phases of invisibility. This difference in result is always found when the data for the Masson disk and the stationary system are compared.

(b) *Comparison of adaptation time and fluctuation time for colors and grays.* (1) *Fluctuation.* Squares of paper were

[1]The writer must apologize to the reader for the ragged appearance of this and the following Tables, owing to the various number of decimal places to which the calculations have been carried out; and must also deprecate any claim to especial accuracy in the case of the longer decimals. He had intended to round-off the figures to two places, but this was inadvertently omitted. Rather than delay the printers, he has allowed the Tables to stand as they were in MS.

pasted upon gray card-board and placed behind an opal glass plate. They were thus seen by reflected light through the opal glass. The intensity was easily regulated by slight changes in the distance of the plate from the card-board. Different makes of standard colors were used at different times. The stimuli for the following Tables were cut from Milton-Bradley papers. The size of the squares was, in each case, 2 cm. x 2 cm., and the distance of the observer 1 meter. All other conditions were the same throughout.

TABLE II.

Ga. Comparison of fluctuation time with adaptation time using colors and grays. Fluctuation: showing that visibility and invisibility have characteristic adaptation and recovery peculiarities.

Stimulus	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Invis.: Vis.	Period
Gray, 2x2 cm.	4.34	1.045	3.50	.727	1.24		7.84
Red, " "	2.26	.53	3.48	.108	.649	1.539	5.74
Green, " "	3.71	.954	3.058	.80	1.213	.824	6.768
Blue, " "	5.68	1.244	3.755	1.181	1.513	.661	9.435
Yellow, " "	8.375	2.075	3.46	.337	2.42	.413	11.835

TABLE III.

S. Comparison of fluctuation time with adaptation time using colors and grays. Fluctuation: showing that visibility and invisibility have characteristic adaptation and recovery peculiarities.

Stimulus	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Invis.: Vis.	Period
Gray, 2x2 cm.	3.47	1.053	2.31	.533	1.502		5.78
Red, " "	1.333	.338	2.8	.527	.4761	2.025	4.133
Green, " "	2.806	.506	2.431	.575	1.154	.866	5.237
Blue, " "	3.2	.836	1.779	.326	1.799	.562	4.979
Yellow, " "	5.576	1.257	1.238	.537	4.504	.221	6.814

TABLE IV.

Ge. Comparison of fluctuation time with adaptation time using colors and grays. Fluctuation: showing that visibility and invisibility have characteristic adaptation and recovery peculiarities.

Stimulus	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Invis.: Vis.	Period
Gray, 2x2 cm.	3.715	.693	2.028	.917	1.832		5.743
Red, " "	1.566	.383	5.95	1.608	.2632	3.799	7.516
Green, " "	3.17	.96	5.6	2.41	.566	1.767	8.77
Blue, " "	4.471	1.157	5.042	1.142	.886	1.127	9.513
Yellow, " "	7.2	1.563	1.354	.355	.288	.188	8.554

TABLE V.

F. Comparison of fluctuation time with adaptation time using colors and grays. Fluctuation: showing that visibility and invisibility have characteristic adaptation and recovery peculiarities.

Stimulus	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Invis.; Vis.	Period
Gray, 2x2 cm.	3.8066	.786	2.54	.466	1.498		6.3466
Red, " "	2.4812	.287	3.362	.568	.737	1.355	5.843
Green, " "	3.55	.462	2.85	.443	1.245	.802	6.40
Blue, " "	3.586	.653	2.793	.7	1.283	.779	6.379
Yellow, " "	4.716	.791	2.141	.366	2.202	.453	6.857

Attention is called again to the fact that, as would be expected from the compensation theory, red and blue have longer phases of invisibility and shorter phases of visibility, respectively, than green and yellow. The relative value of the invisibilities as compared with the visibilities in each case is expressed by the ratio invisibility: visibility.

(2) *Adaptation.* To test the correspondence of these results with those obtained from adaptation, sheets of colors of the same make were placed behind lightly frosted glass and observed at distances ranging from 2-3 meters. Just how much the intensity was lowered by these conditions we are not able to say,—probably not one half. This does not matter, however, so long as each color was tested under precisely the same conditions, since only comparative values were wanted. The following results were obtained:

Obs. *G*. Distance: 235 cm. Time unit: 1 sec.

Red	41.
Green	55
Blue	78
Yellow	263

Because of the severe eye-strains, the intensity was further reduced for *F* by placing the color 11 cm. behind the frosted glass.

Obs. *F*. Distance: 235 cm. Time unit: 1 sec.

Red	25
Green	41
Blue	58
Yellow	225

For *S*, the color was placed 19 cm. behind the frosted glass.

Obs. *S*. Distance: 300 cm. Time unit: 1 sec.

Red	19
Green	52
Blue	160
Yellow	196

The order is the same as was obtained in the fluctuation experiments; and a comparison of the Tables will show that a rough correspondence holds in the ratios sustained between the phases of visibility and the adaptation times in each case.

It may be objected that the colors used were not standardized. We are, however, not attempting to state results for standard colors. Our sole aim is to show correspondence between adaptation and fluctuation. This has been accomplished by using identical colors in the two sets of experiments. It could have been done no better, we believe, by using standard colors.

(c) *Combinations of stimulus and background that influence adaptation time correspondingly influence fluctuation time.* (1) *Fluctuation.* For this point so far the Masson disk has been used. From all the colors tried as background, light greenish blue (Hering), yellowish green (Milton-Bradley), yellow (Milton-Bradley), orange (Hering), gray, and in one case dark red (Milton-Bradley) were selected for the following Tables. The stimulus strips were 2 mm. x 5 mm., and were placed 8 mm. apart along the radius. They were, with one exception, of Hering red.

This method we consider very unsatisfactory. In the first place, results never stand out so clearly with the Masson disk as when the system is at rest: judgments are difficult; distractions are many, and gradations of intensity, neither so constant nor even so delicate, can be obtained. And, secondly, as our disks were made, the stimulus color was rendered liminal by mixing with the color of the background rather than with a gray of its own brightness. If we take, for example, a red stimulus upon a light blue background, the effect obtained was a faintly reddish blue upon a blue background, slightly differing from it in brightness. But even this approximation to the desired conditions was sufficient to vary the phase of visibility to a rough correspondence with the results obtained with a similar combination of stimulus and background in the adaptation experiments.

(2) *Adaptation.* Here, likewise, red at *full intensity* disappears most readily upon the light blue; not quite so readily upon the gray used; and never entirely goes into the background, although the color is lost periodically, upon the orange, yellow, and yellowish green. Yellow on dark red is peculiarly persistent.

In addition to the combinations here used, we have tried a number both of grays and of colors, and are satisfied that whatever alters the conditions for adaptation correspondingly alters the conditions for fluctuation.

(d) *Method of variation of areas.* (1) *Fluctuation.* This

TABLE VI.

Ga. Combinations of stimulus and background that influence adaptation time correspondingly influence fluctuation time. Fluctuation.

Stimulus	Background	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Red, 2x5 mm.	Light Blue	2.287	.681	3.362	.631	.6803	5.649
" " "	Yellow	4.609	.1141	2.78	.600	1.6856	7.388
" " "	Orange	4.709	.1127	2.936	.663	1.600	7.645
" " "	Yellowish Green	4.130	1.161	2.715	.800	1.521	6.845
" " "	180° Engine Gray + 180° Velvet Black	3.615	1.076	3.268	1.1	1.106	6.893
Yellow, 2x5 mm.	Dark red	6.512	1.012	3.887	.912	1.675	10.399

TABLE VII.

F. Combinations of stimulus and background that influence adaptation time correspondingly influence fluctuation time. Fluctuation.

Stimulus	Background	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Red, 2x5 mm.	Light blue	2.9	.398	3.164	.58	.969	6.064
" " "	Yellow	4.73	.52	2.96	.4	1.598	7.69
" " "	Yellowish Green	4.4	.717	3.2	.37	1.375	7.60
" " "	180° Engine Gray + 180° Velvet Black	2.9	.292	2.95	.628	.983	5.85

method was tried both upon the Masson disk and with the opal glass plate as a background. The results in both cases were unquestionable; but, as before, those given by the stationary system were much the more satisfactory and much the more clearly cut. Because of this, and chiefly because the disk did not permit enough variation of area, the Masson disk will be omitted from further consideration in this paper.

A stimulus was obtained upon the opal glass plate by light coming from a bank of lamps behind it, passing first through a plate of frosted glass, then through the opal glass itself. The magnitude of the stimulus was regulated by a card-board diaphragm behind the screen; its intensity, by varying the distance of the lamps, also by means of a curtained window in front. This photometric arrangement provided a very sensitive means of obtaining a just noticeable stimulus. After the initial adjustment was made, great care was taken that the illumination of the background should remain constant throughout the experiment.

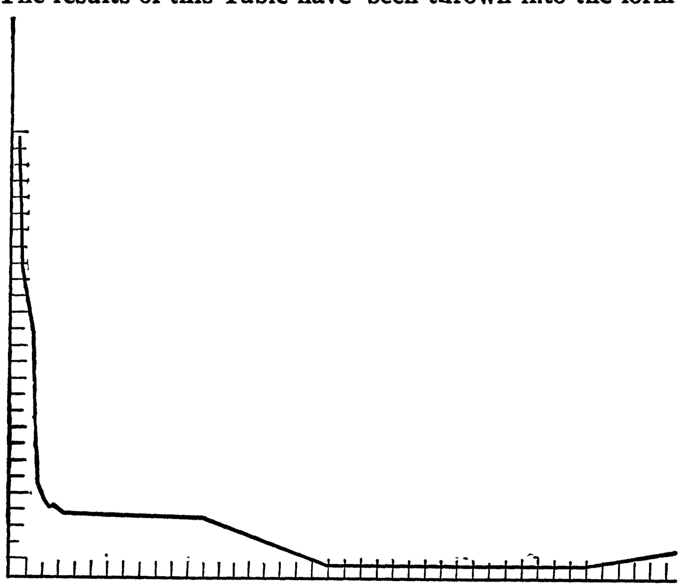
TABLE VIII.

F. Method of variation of areas. Fluctuation: showing inverse variation of visibility and invisibility with increase of area.

Area	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
2x 2 mm.	16.86	4.83	.8	.28	21.075	17.66
4x 4 "	12.93	3.53	1.15	.38	11.24	14.08
6x 6 "	10.78	3.8	2.9	.83	3.71	13.68
8x 8 "	5.65	1.53	2.76	.52	2.23	8.41
10x10 "	4.74	1.32	2.34	.63	2.023	7.09
12x12 "	4.22	.97	2.72	.57	1.551	6.94
14x14 "	4.35	1.29	3.2	.46	1.359	7.55
16x16 "	3.96	1.22	2.918	.59	1.360	6.878
6x 6 cm.	3.73	1.11	5.2	.77	.717	8.93
10x10 "	.81	.23	9.65	2.8	.073	10.46
14x14 "	.8	.5	29.46	4.66	.027	30.26
18x18 "	.85	.45	40.25	2.25	.021	40.10
22x22 "	1.4	No reappearance.				

For *F*, beginning at areas ranging from 10 cm. x 10 cm.—14 cm. x 14 cm. in the different records, it was noticed that only the edge of the lower left hand corner and left side reappeared.

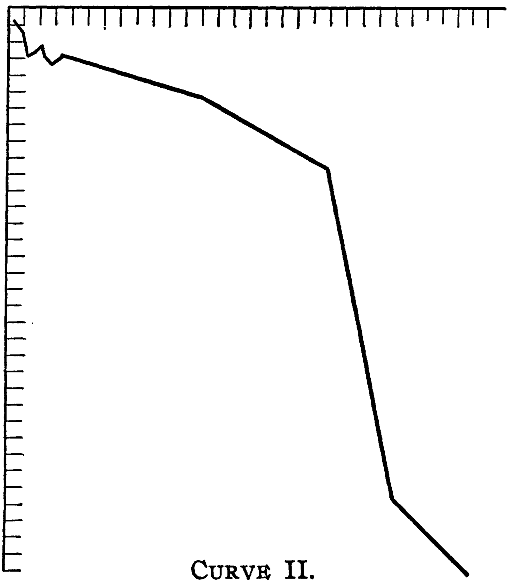
The results of this Table have been thrown into the form of



CURVE I.

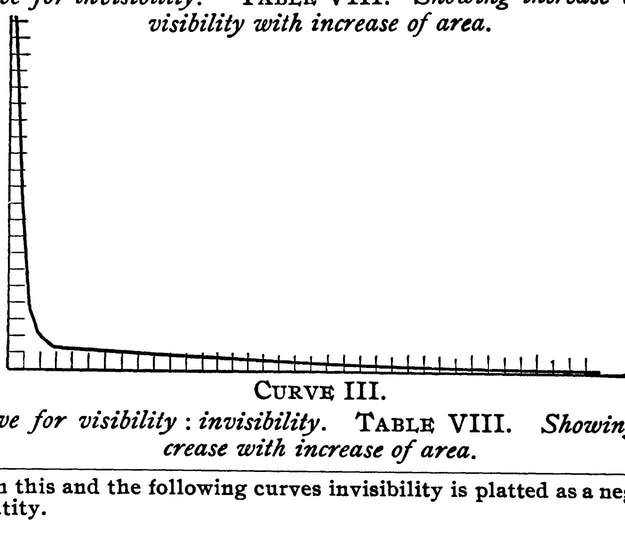
Curve for visibility. TABLE VIII. *Showing decrease of visibility with increase of area.*

a curve. The dimensions of the stimulus are laid off along the abscissa, millimeter for millimeter; the time values along the ordinate, on the scale of 1 second to 5 millimeters. The last and more horizontal part of the curve for visibility represents the reappearance of the edge of the left side and the lower left hand corner.



CURVE II.

Curve for invisibility.[1] TABLE VIII. *Showing increase of invisibility with increase of area.*



CURVE III.

Curve for visibility : invisibility. TABLE VIII. *Showing decrease with increase of area.*

[1] In this and the following curves invisibility is platted as a negative quantity.

TABLE IX.

Ga. Method of variation of areas. Fluctuation: showing inverse variation of visibility and invisibility with increase of area.

Area	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
2x 2 mm.	7.3	1.31	2.122	.466	3.44	9.422
4x 4 "	6.34	1.38	2.94	.46	2.16	9.28
8x 8 "	4.53	1.066	3.24	.558	1.39	7.77
12x12 "	4.23	1.45	3.75	.53	1.12	7.98
16x16 "	4.03	.933	3.9	.708	1.03	7.93
6x 6 cm.	1.83	.58	5.675	1.89	.32	7.505
10x10 "	1.19	.436	6.96	2.8	.17	8.15
16x16 "	.61	.1	12.53	3.3	.048	13.14
26x26 "	.725	.175	25.36	6.067	.028	26.085
34x34 "	.55	.2	25.13	4.3	.021	25.68
42x38 "	.8	No reappearance.				

For *Ga*, with an area of 10 cm. x 10 cm., only about one third of the area covering the lower left hand corner reappeared. From that area on, the part reappearing became less and less, until finally there was no reappearance at all.

The reappearance of the lower left hand corner alone in the case of the larger areas led to the belief, after a time, that the stimulus was stronger in this region. This was all the more probable, because the window was somewhat above and to the right of the observer, thereby illuminating the background around this corner slightly less than the rest of the field. In consequence, this part of the stimulus stood out slightly supraliminally. To obviate this difficulty, stimuli of Hering gray, no. 27, were pasted upon engine-gray card-board and placed behind the opal glass plate. The intensities were easily regulated by slight changes in the distance of the plate from the card-board. Since both stimulus and background were now seen by reflected light, the former inequality of relation between them was impossible. The rather remarkable change of results obtained makes it worth while to note the following Tables.

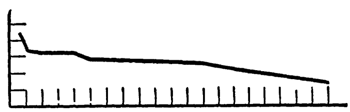
TABLE X.

F. Method of variation of areas. Fluctuation: showing inverse variation of visibility and invisibility with increase of area.

Area	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
3x 3 mm.	4.435	.742	4.285	.835	1.035	8.72
6x 6 "	3.372	.854	6.772	1.218	.498	10.144
10x10 "	3.327	.5	11.562	1.937	.287	14.889
20x20 "	3.31	.71	12.975	1.84	.255	16.285
25x25 "	2.962	.427	14.36	2.812	.206	17.322
6x 6 cm.	1.533	.333	38.00	.723	.0403	39.533
10x10 "	1.145	No reappearance.				

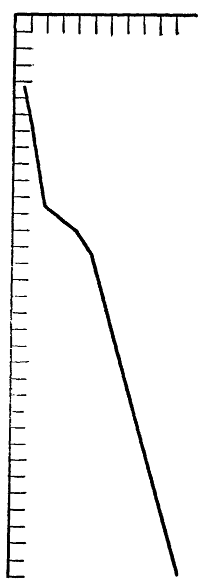
Curves were plotted from these results to compare with those obtained from Table VIII.

It will be noticed that this series began with an area of 3 mm. x 3 mm. In the former case, it was 2 mm. x 2 mm.



CURVE IV.

Curve for visibility. TABLE X. *Showing decrease of visibility with increase of area.*



CURVE V.

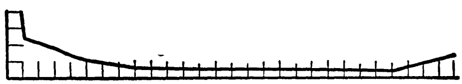
Curve for invisibility. TABLE X. *Showing increase of invisibility with increase of area.*

TABLE XI.

Ga. Method of variation of areas. Fluctuation: showing inverse variation of visibility and invisibility with increase of area.

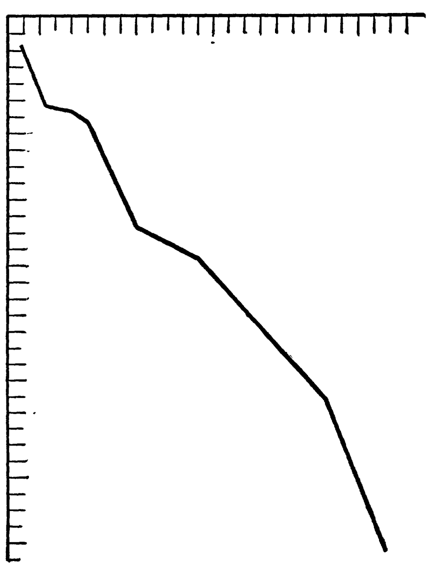
Area	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
4x 4 mm.	4.466	1.26	1.853	.406	2.41	6.319
6x 6 "	2.385	.910	2.934	.828	.812	5.319
12x12 "	2.000	.537	5.257	1.600	.380	7.257
16x16 "	1.984	.761	5.269	1.768	.376	7.253
20x20 "	1.453	.615	5.557	2.050	.261	7.010
25x25 "	1.122	.321	6.100	1.538	.183	7.222
4x 4 cm.	.775	.225	12.583	3.266	.061	13.358
6x 6 "	.716	.200	14.460	4.216	.049	15.176
10x10 "	.632	.197	23.100	3.500	.027	23.732
12x12 "	.590	.284	33.866	7.445	.017	34.456
14x14 "	1.5	No reappearance.				

The following curves represent the results of the preceding Table. The first area used is 4 mm. x 4 mm.



CURVE VI.

Curve for visibility. TABLE XI. *Showing decrease of invisibility with increase of area.*



CURVE VII.

Curve for invisibility. TABLE XI. *Showing increase of invisibility with increase of area.*

TABLE XII.

Ge. Method of variation of areas. Fluctuation: showing inverse variation of visibility and invisibility with variation of area.

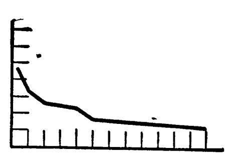
Area	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
3x 3 mm.	5.43	1.5	3.192	1.169	1.732	8.622
6x 6 "	3.14	1.033	4.3	.930	.730	7.44
10x10 "	2.469	.953	6.09	.305	.305	8.559
20x20 "	2.16	.72	15.683	4.016	.137	17.843
25x25 "	1.185	.255	18.342	3.342	.064	15.75
6x 6 cm.	.7	.133	27.75	5.85	.025	28.45
10x10 "	1.2	No reappearance.				

TABLE XIII.

S. Method of variation of areas. Fluctuation: showing inverse variation of visibility and invisibility with increase of area.

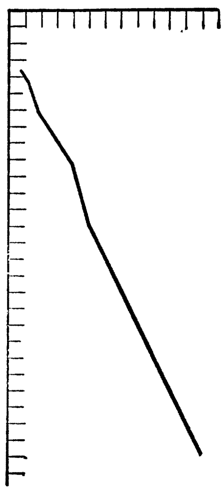
Area	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
3x 3 mm.	4.683	1.26	2.28	.633	2.05	6.963
6x 6 "	3.66	.686	2.26	.626	1.619	5.92
10x10 "	2.876	.557	2.33	.495	1.234	5.206
16x16 "	2.521	.643	2.57	.556	.980	5.091
20x20 "	2.23	.709	2.80	.668	.796	5.030
4x 4 cm.	2.08	.625	2.98	.565	.697	5.06
8x 8 "	2.288	.594	3.805	1.047	.600	6.093
12x12 "	2.03	.523	5.361	1.230	.378	7.391
16x16 "	1.7	.514	12.9	2.385	.131	14.600
18x18 "	1.5	No reappearance.				

The averages of the visibilities and invisibilities of Tables X, XI, XII, and XIII were plotted up to the area 6 cm. x 6 cm., the last reappearance recorded for *F* and *Ge*.



CURVE VIII.

Curve for visibility. Averaged from Tables X, XI, XII, and XIII. *Showing decrease of visibility with increase of area.*



CURVE IX.

Curve for invisibility. Averaged from Tables X, XI, XII, XIII. *Showing increase of invisibility with increase of area.*

It will be noticed, in the above Tables, that the area at which fluctuation ceases has been decreased to one-fourth in the one case and to one-eighth in the other. This, we believe, is due solely to the inequality in intensity of the stimulus obtained by the former method, for it will be observed that the area at which the stimulus began to recur in parts in the former Tables nearly coincides with that at which fluctuation ceased in the latter.

It will be seen, also, that in the case of the smaller areas the phases of visibility have been decreased and the phases of invisibility increased. Sufficient explanation for this result can be found, most probably, in the different conditions for adaptation present in the two cases. It will be well, at least, to point them out.

(*a*) Although of no greater intensity, the stimulus area was more sharply defined than the area given by the reflected light. The latter was somewhat diffuse and spreading, and to a certain degree gave the effect of a larger area. This slight change would be appreciable for the smaller areas, but not for the larger. (*b*) The side of the opal glass used for the background in the former case was polished and shining. This was trying to the eyes of the observer, the strain relieving itself in increased eye-movement and blinking. The side used in the latter case was dull and chalky, and produced no particular discomfort. (*c*) In the former case, the minimal difference to

be adapted out was between a bright white background and a still brighter stimulus. In the latter case, it was between a dull, chalky background and a darker stimulus. Just what effect this difference would have on adaptation we are not able to state. It seems reasonable to believe, however, that the process would not be uniform at all points in the white-black series. In fact records were obtained indicating that, in general, this is true; unfortunately, however, they were made early in the work, and were not arranged for a particular confirmation of results under these precise conditions. As nearly as can be determined from them, planned as they were, the process is more rapid at the extremes of the white-black series (indicated by the shorter phases of visibility here obtained) than in the mid-region of neutral grays. The stimulus just noticeably lighter than a black background, too, seems to give slightly shorter phases of visibility than a stimulus just noticeably darker than a white background. It will be understood that these results are not intended to apply to adaptation any further than for the obliteration of just noticeable differences. But from the data we may draw the very general conclusion that the value of just noticeable differences for adaptation, even in the white-black series, depends upon the sort of combination used.

It is important to note that while Lange[1] finds approximate equality in the periods obtained from three sense departments, and argues therefrom a central origin, it is found here that a change of conditions so slight as to have passed unnoticed, had not the results demanded investigation, brings a wide range of variability, although not even a change in the retinal elements stimulated is involved, *i. e.*, both series of combinations of stimulus and background are in the white-black series.

Another point noticeable in these records, and throughout the work in general, is the large mean variation. This is especially obvious when large areas are used, or whenever from any cause either visibility or invisibility approaches infinite value. It is due, chiefly, to one or two very long phases of visibility or very short phases of invisibility, or conversely; the phenomena depending upon which extreme of the phase variation one is considering. Slaughter[2] believes that there is a connection between these recurring long phases of visibility, obtained with stimuli of the usual order, and the Traube-Hering waves. It seems, however, much more probable that their immediate condition is to be found in eye-movement. In unsteady fixation, the eye oscillates, *i. e.*, in recovering fixation,

---

[1] *Philosophische Studien*, IV, 390.
[2] *Op. cit.*

it overdoes, swinging to the other side and back again, etc. Eye-movements come in groups. One or more of these groups occurring within a phase of visibility, will prolong it very much; or falling within a phase of invisibility will shorten it proportionately. These facts are brought out plainly in the records for eye-movement.

That extensive voluntary eye-movement will not cause the reappearance of the faded-out stimulus, provided sufficiently large areas are used, was confirmed for *Ga* and *S*. An area of opal glass 30 cm. square was made just noticeably red by light transmitted through red paper covering its back. Three fixation points were made the apices of an equilateral triangle, circumscribed about the centre of the plate. The observer, seated at a distance of 98 cm., allowed the color to adapt out, and then shifted his eyes along the sides of the triangle from fixation point to fixation point in order. The following results were obtained:

Ga. With 2 cm. eye-movement (in each direction) . . . . . . Slight reappearance at edges only.

With 3.3 cm. eye-movement. . . . . . . Began to get a wash of color farther in from the edges.

With 4 cm. eye-movement. . . . . . . Color returned a little more perceptibly over central area.

S reported no change at all until 4.9 cm. of eye-movement in each direction were reached. Then there was a slight wash of color, pretty much over the whole area. Had he observed more closely, he probably would have noticed the changes at the edges sooner than this.

The intensity of the stimulus was increased considerably above the limen, and the same method carried out with similar results. A larger area, however, had to be used with the same range of movement.

These facts speak strongly against innervation as the cause of the reappearance of the adapted out stimulus. Much more plausible does it seem that restoration comes about on account of actual change of stimulation of the adapted elements.[1]

(2) *Adaptation*. The following Tables show the effect of variation of area for recognized adaptation phenomena. The combinations of stimulus and background chosen are the most favorable for intermittence. Fluctuations of intensity may be had from any combination, but complete disappearances take place most readily with those here selected. The eye-strain involved and the consequent unsteady fixation make the phenomenon somewhat difficult to obtain.

[1] Together with the supplementary process mentioned but not specified above.

TABLE XIV.

Ga. Method of variation of areas. Adaptation: showing inverse variation of visibility and invisibility with increase of area.

Stimulus	Background	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Red, 1x 5 mm.	Blue	No disappearance.					
" 2x 5 "	"	4.64	.98	1.175	.325	3.95	5.815
" 5x 5 "	"	2.77	.601	4.19	1.16	.66	6.96
" 10x10 "	"	1.4	.34	4.44	1.24	.31	5.84
" 2x35 "	"	1.68	.58	3.35	1.09	.5	5.03
Hering Gray, (no. 27) 1x 5 mm.	Hering Gray, (no. 33)	No disappearance.					
" 2x 5 "	"	27.915	1.423	.54	.223	51.694	28.455
" 5x 5 "	"	9.450	2.617	1.568	.57	6.057	11.018
" 10x10 "	"	6.787	2.25	2.275	.325	2.983	9.062
" 2x35 "	"	10.36	3.07	1.485	.285	6.976	11.846

TABLE XV.

E. Method of variation of areas. Adaptation: showing inverse variation of visibility and invisibility with increase of area.

Stimulus	Background	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Red, 1x 5 mm.	Blue	9.5627	2.66	1.075	.175	8.895	10.637
" 3x 5 "	"	4.237	1.07	1.381	.281	3.067	5.618
" 7x10 "	"	1.878	.255	2.863	.594	.656	4.741
" 1x 5 "	Gray	3.542	1.071	10.471	2.514	.3383	14.013
" 5x 5 "	"	2.06	.480	8.55	1.71	.2409	10.61

F. ADAPTATION IS RENDERED INTERMITTENT CHIEFLY BY EYE-MOVEMENT.

"Even in fixation intended to be constant, as in the present investigation, it is not likely that the eye was motionless for the eight to thirty seconds during which the experiment lasted, as McAllister has recently pointed out that the eye is seldom at rest for one-ninth of a second continuously. At least it would be most unlikely that it should be absolutely at rest for so long a period as twenty seconds and then move unconsciously at the end of that time." [1]

The inference contained in the above quotation is that, if eye-movement causes relief of the adapted elements sufficient to bring about reappearance when complete adaptation has once set in, disappearance should never have occurred;

[1] W. B. Pillsbury: *The Journal of Philosophy, Psychology, and Scientific Methods*, II, 272. Review of *Zur experimentellen Kritik der Theorie der Aufmerksamkeitsschwankungen*, by B. Hammer.

for the eye is moving almost continuously, and each movement should have relieved the adaptation that had taken place previous to it. Pillsbury has, however, probably not considered that range of movement is a factor as well as frequency. If the eye moved nine times a second with sufficient range, there probably never would be noticeable adaptation for small areas. How far this supposition is from the facts, however, is shown by our results. The average interval between movements extensive enough to produce a noticeable shift of the after-image in either the horizontal or vertical plane, viewed at a distance of 1 meter (and certainly smaller movements could scarcely be considered to bear upon the point in question), ranges from $\frac{4}{5}$ sec.-$2\frac{1}{4}$ sec. The average time between movements shifting the after-image 2 mm. in either plane ranges from $1\frac{1}{2}$ sec.-$2\frac{1}{2}$ sec.; 4 mm., from $2\frac{1}{7}$ sec.-48 sec.; 6 mm., from $3\frac{1}{3}$ sec.-96 sec., etc. Now it will be remembered that the movements in each plane came in groups of two and three, so that these intervals in most cases should be so much multiplied. According to this account, there seems to be ample opportunity for adaptation to take place, when range of movement is taken into consideration as well as frequency. Movements as small as those referred to by McAllister would probably produce some effect in delaying adaptation; but complete restoration before the stimulus has adapted out, or reappearance after it has disappeared, is doubtless caused by groups of movements of considerable range.

The range of movement required will, of course, depend upon the stimulus area used. When the area is very small, Pillsbury's inference holds; there is no disappearance. The restoration afforded by eye-movement here cancels the effect of adaptation before disappearance takes place. This is one of the points brought out by our method of areas. On the other hand, with areas varying from 10 cm. x 10 cm. — 14 cm. x 14 cm., the range of movement for our observers was not great enough ever to produce reappearance. And with still larger areas, extensive voluntary movements did not suffice even to revive the lost sensation.

We do not assert that the statement quoted, considered as a criticism of Hammer's article, is not well grounded. This article is chiefly suggestive. But, on the other hand, it is only fair to remember that it requires positive knowledge to overthrow as well as to establish a theory. Both statement and criticism should, with equal care, be based upon ample investigation. That eye-movement, blinking, etc., interfere with the course of adaptation is not a recently discovered fact, nor is it a closed subject. Local adaptation still presents a fruitful field for research.

With the help of the data submitted in this article, we trust that no intrinsic difficulty will be found in the conception that adaptation is rendered intermittent by eye-movement. Aside from this, too, there remains, further to strengthen the theory, the supplementary factor (not yet specified) which works in conjunction with the relief afforded by a shift of the adapted elements into a region of different stimulation.

For the investigation of eye-movement, a method had to be selected that would not be objectionable to the observers, and would not interfere with the normal course of the phenomenon either mechanically or by way of distraction. The shifting of the negative after-image during fixation afforded a method somewhat rough, but adequate for our purpose. Colored strips, 5 mm. x 40 mm., were used as stimuli. They were pasted on a background of white card-board, with the shorter dimension in the plane in which the eye-movement was to be investigated. The determination of frequency then became merely a matter of recording the appearance of the after-image to the right or left or above or below the stimulus, separate series being made for both planes. For the determination of range of movement, narrow strips of paper of the same brightness as the background were placed successively 2, 4, 6, 8, etc., mm. from the stimulus, and only those movements recorded that caused the after-image to shift to or beyond these strips. The strips were so inconspicuous as not to attract the eye away from the fixation point; still, it was not difficult to judge when the after-image reached, or passed beyond them. They were always used, also, when frequency alone was to be determined, in order that the same conditions might prevail throughout. Some periods were given up wholly to the investigation of eye-movement alone, thus determining the type in general; while again the eye-movement tracing was alternated with the corresponding fluctuation tracing, in order to establish a more immediate connection between the eye-movements in either plane and the phases of visibility and invisibility in that plane. Doubtless, it would have been better to have the eye-movement recorded while the fluctuation was in progress, could this have been done without interfering with the normal course of the phenomenon. As it was, however, enough results were obtained to render conclusions safe as to the type of the observer.

The stimuli in both the eye-movement and fluctuation experiments were of the same dimensions, and were arranged in precisely the same way. The distance of the observer, throughout, was 1 meter. The color of the stimulus was selected with reference to the vividness of the after-image for the particular observer. Milton-Bradley standard green was used for *S*, *Ga*,

Ge, while red of the same make gave the best results for *F*. The expression: 'stimulus vertical' will be used when the longer dimension of the strip is placed in the vertical plane, and 'stimulus horizontal' for the corresponding arrangement in the horizontal plane.

The following results were obtained:

(a) *Eye-movement in the horizontal and vertical planes.*

S. Length of observation: 97 sec.

Stimulus vertical.

Strips 2 mm. distant. Recorded all,	55
All reaching to strips 2 mm. distant,	26
" " " " 4 " "	11
" " " " 6 " "	4

Stimulus horizontal.

Strips 2 mm. distant. Recorded all,	39
All reaching to strips 2 mm. distant,	21
" " " " 4 " "	9
" " " " 6 " "	2

The results here show greater range and greater frequency in the horizontal plane. The records also demonstrated that the recovery was quicker in this plane.

Ge. Length of observation: 94 sec.

Stimulus vertical.

Strips 2 mm. distant. Recorded all,	46
All reaching to strip 4 mm. distant,	40
" " " " 6 " "	14
" " " " 8 " "	7
" " " " 10 " "	2

Stimulus horizontal.

Strips 2 mm. distant. Recorded all,	30
All reaching to strip 2 mm. distant,	25
" " " " 4 " "	14
" " " " 6 " "	0

It will be noticed that the excess of range in the horizontal plane in this Table is considerably greater than the excess of frequency. There is quicker recovery also in the horizontal plane.

Ga. Length of observation: 96 sec.

Stimulus vertical.

Strips 2 mm. distant. Recorded all,	35
All reaching to strips 2 mm. distant,	31
" " " " 4 " "	2
" " " " 5 " "	1

Stimulus horizontal.

Strips 2 mm. distant. Recorded all,	81
All reaching to strips 2 mm. distant,	9
" " " " 4 " "	0

This Table shows greater frequency in the vertical and greater range in the horizontal plane. In the next Table the experiments for range were not carried out. The following averages for frequency were obtained:

F. Length of observation, 104 sec.

Stimulus vertical, 29
" horizontal, 17

Towards the end of the hour, for each observer, the records showed increase of eye-movement, as the result of fatigue.

(b) *Fluctuation with vertical and horizontal arrangement of the stimulus.*

The following are the results obtained for the fluctuation experiments. The stimulus was rendered liminal by being placed behind a plate of opal glass.

TABLE XVI.

S. Fluctuation with vertical and horizontal arrangement of the stimulus. Showing how arrangements that favor maximal and minimal interference with adaptation affect the phases of visibility and invisibility.

Stimulus	Arrangement	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Gray, 5x40 mm.	Vertical	5.3545	1.027	2.4727	.690	2.165	7.8272
" " "	Horizontal	3.0733	.426	2.7066	.666	1.135	5.7799
Red, " "	Vertical	3.152	.917	1.641	.453	1.9207	4.793
" " "	Horizontal	2.358	.452	2.436	.621	.968	4.794
Green, " "	Vertical	4.986	1.06	1.493	.413	3.340	6.479
" " "	Horizontal	3.260	.526	2.546	.786	1.2804	5.806
Yellow," "	Vertical	5.0611	.911	1.588	.511	3.187	6.6491
" " "	Horizontal	4.642	.580	2.542	.371	1.825	7.1856

TABLE XVII.

Ge. Fluctuation with vertical and horizontal arrangement of the stimulus. Showing how arrangements that favor maximal and minimal interference with adaptation affect the phases of visibility and invisibility.

Stimulus	Arrangement	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Gray, 5x30 mm.	Vertical	3.873	.873	2.32	.933	1.669	6.193
" " "	Horizontal	3.825	.983	3.458	1.075	1.135	7.283
" 5x40 "	Vertical	4.006	1.293	2.526	.733	1.585	6.533
" " "	Horizontal	1.407	.268	4.423	1.153	.3181	5.830
" 5x50 "	Vertical	4.353	.822	2.700	.868	1.6123	7.053
" " "	Horizontal	2.700	1.071	3.285	.778	.8217	5.985
Green, 5x40 "	Vertical	4.400	1.054	4.981	1.172	.8833	9.381
" " "	Horizontal	2.663	.490	5.481	1.154	.4857	8.144

TABLE XVIII.

Ga. *Fluctuation with vertical and horizontal arrangement of the stimulus. Showing how arrangements that favor maximal and minimal interference with adaptation affect the phases of visibility and invisibility.*

Stimulus	Arrangement	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Gray, 10x50 mm.	Vertical	2.655	.644	6.422	1.333	.4135	9.077
" " "	Horizontal	3.336	.763	5.545	1.418	.6016	8.881
Yellow, 2x40 "	Vertical	3.807	1.115	3.223	.915	1.181	7.030
" " "	Horizontal	6.96	1.987	2.45	.801	2.8408	9.41

TABLE XIX.

F. *Fluctuation with vertical and horizontal arrangement of the stimulus. Showing how arrangements that favor maximal and minimal interference with adaptation affect the phases of visibility and invisibility.*

Stimulus	Arrangement	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Red, 5x40 mm.	Vertical	4.8685	1.29	3.495	.775	1.392	8.3635
" " "	Horizontal	3.038	.646	3.753	1.092	.809	6.791

(c) *Adaptation with vertical and horizontal arrangement of the stimulus.*

That the same arrangement is effective with stimuli at full intensity was confirmed by experiments upon *Ga.* A strip of Hering red, 5 mm. x 30 mm., was pasted on a square of Hering light blue, 20 cm. x 20 cm., and viewed at a distance of 2 meters.

TABLE XX.

Ga. *Adaptation with vertical and horizontal arrangement of the stimulus. Showing the interference caused by the vertical and horizontal arrangements.*

Stimulus	Arrangement	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Red, 5x30 mm.	Vertical	2.24	.671	4.014	.914	.558	6.254
" " "	Horizontal	3.987	.727	3.775	.887	1.056	7.762

G. CORRESPONDENCE OF FLUCTUATION WITH ADAPTATION IN INDIRECT VISION.

(a) *Fluctuation.* In the fluctuation experiments in indirect vision, the stimuli were rendered liminal by the use of the opal glass plate, as before. The observer was seated at a distance of 1 meter and given a fixation point in the median line. It

will be noticed in these results, as also in the Tables for the method of variation of areas, that the average phase of visibility increases slightly at the end of the Table. The reason is that in each tracing the phase of visibility is greatest at the beginning and decreases considerably towards the end. Now in the last series of the Table there are few and, at the very last, no phases of visibility to average with these maximal first phases; consequently the curve rises a little at the lower end. For the same reason, the mean variation for both visibility and invisibility increases towards the end of the Table.

The results obtained are given in the following Tables. The points to be noticed are the effects of variation of area and passage of stimulus towards the periphery.

TABLE XXI.

Ga. Correspondence of fluctuation with adaptation in indirect vision. Fluctuation: showing the effect of increase of area and passage of stimulus towards the periphery.

Stimulus	Distance from fixation	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Gray, 8x8 mm.	0 cm.	2.335	.67	2.38	.485	.985	4.715
" " "	4 "	1.527	.383	3.52	.993	.434	5.047
" " "	8 "	1.13	.345	7.35	2.212	.153	8.48
" " "	12 "	1.08	.39	8.73	2.157	.123	9.81
" " "	20 "	.566	.1	13.38	4.8	.0423	13.946
" " "	24 "	.633	.06	34.53	12.	.018	35.163
" 6x6 cm.	0	1.49	.64	6.33	1.73	.235	7.82
" " "	4 "	1.177	.355	8.411	2.07	.140	9.588
" " "	8 "	.628	.214	10.685	2.514	.0588	11.312
" " "	12 "	.625	.175	23.125	3.875	.0265	23.75
" " "	20 "	.250	.03	43.25	7.282	.0057	43.75
" " "	24 "	.2	No reappearance.				

TABLE XXII.

F. Correspondence of fluctuation with adaptation in indirect vision. Fluctuation: showing the effect of increase of area and passage of the stimulus towards the periphery.

Stimulus	Distance from fixation	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Gray, 5x5 mm,	0 cm.	4.12	.83	2.41	.50	1.709	6.53
" " "	8 "	1.671	.507	4.514	.102	.370	6.185
" " "	12 "	1.187	.5	9.625	2.28	.122	10.812
" " "	20 "	.433	.123	22.25	4.82	.0194	22.683
" 6x6 cm.	0 "	2.35	.46	4.77	1.13	.492	7.12
" " "	8 "	2.24	.65	14.04	3.158	.1592	16.28
" " "	20 "	1.5	No reappearance.				

TABLE XXIII.

Ge. Correspondence of fluctuation with adaptation in indirect vision. Fluctuation: showing the effect of increase of area and passage of stimulus towards the periphery.

Stimulus	Distance from fixation	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Gray, 6x6 mm.	0 cm.	3.975	1.21	4.187	1.33	.949	8.162
" " "	8 "	2.1875	1.1	8.4	.24	.2604	10.5875
" " "	12 "	1.128	.285	1.528	3.045	.09785	12.656
" " "	20 "	.79	.25	11.04	.665	.0715	11.83
" " "	28 "	.5	.21	11.728	2.971	.0426	12.228
" " "	34 "	.375	.1	11.987	2.446	.0312	12.362
" " "	43 "	.5	.2	44.9	9.62	.0111	45.4
" 6x6 cm.	0 "	.62	.22	22.75	4.64	.0272	22.97
" " "	8 "	.7	.2	42.6	9.89	.0151	43.3
" " "	12 "	1.	No reappearance.				

(b) *Adaptation.* That stimuli at full intensity show the same law of inverse variation of visibility: invisibility from direct vision towards the periphery was verified by *Ga.* Hering standard red upon a background of engine-gray card-board (neutral shade) was used.

TABLE XXIV.

Ga. Correspondence of fluctuation with adaptation in indirect vision. Adaptation: showing the effect of passage of stimulus towards the periphery.

Stimulus	Distance from fixation	Vis.	M. V.	Invis.	M. V.	Vis.: Invis.	Period
Red, 8x8 mm.	8 cm.	15.916	3.25	.2	.033	79.58	16.116
" " "	12 "	6.575	2.05	1.683	.475	3.907	8.258
" " "	20 "	4.293	1.13	2.656	.925	1.612	6.949
" " "	24 "	4.89	1.05	3.35	1.151	1.46	8.24
" " "	34 "	3.2	1.192	5.5	1.107	.581	8.7
" " "	42 "	2.9	.766	6.583	1.208	.440	9.73
" " "	50 "	2.33	.86	9.26	2.32	.240	11.56
" " "	60 "	.45	No reappearance.				

The adaptation times in indirect vision were also obtained for the same stimulus. The background in this case was, as before, the neutral engine-gray card-board. The time required completely to adapt out the stimulus was recorded. This, an adaptation experiment in its purest form, shows that the time required to adapt out the stimulus decreases as we go towards the periphery. One may suggest the following reasons why this decrease should occur:

(1) Decrease of the retinal stuff towards the periphery. This would certainly be true for colored stimuli.

(2) Since the eye is approximately spherical in form, and the aperture is near the front surface, one might expect less absolute change of stimulation area towards the periphery on account of eye-movement. Experiments to test the matter, by the same method as was used in direct vision, showed a marked decrease in the number of eye-movements recorded as the stimulus was moved towards the periphery. Whether this was because there was actually less range of movement of the after-image, or was due solely to the greater difficulty of observation, we are not able to state. The fact that there was a greater decrease in range than in frequency would seem to indicate that the effect was not wholly due to increased difficulty of observation.

(3) A further reason will be discussed when we deal with the fluctuation of after-images.

The observer sat with eyes closed and registration key up. The drum was started. At a signal the observation was begun and the key pressed down. When the color had adapted out, the key was released. The results were as follows:

Ga. Time unit: 1 sec.

Stimulus 8 cm. from fixation,	15.8
" 12 " " "	9.7
" 20 " " "	5.0
" 28 " " "	4.8
" 54 " " "	2.8

II. Cutaneous Stimuli.

(a) *Pressure.* Liminal pressure stimuli were applied to several observers, but no fluctuations were experienced. Very smooth cork wafers supporting minimal weights were used, and every care was taken to insure uniformly distributed, pure pressure sensations.

(b) *Electro-cutaneous.* Liminal electro-cutaneous stimulation was also tried. The tip of the tongue was selected as the area most sensitive to stimulation. Strips of very light tin foil (Christmas-tree foil) were used as electrodes. The moist surface of the tongue readily held these in place. There was no preliminary sensation of pressure or contact. The observer was not even able to tell that the strips were in place when the current was off. A Du Bois-Reymond sledge was chosen as giving the most easily regulated induction current. The observer was seated in a distant room, his head fixed in a head-rest, and the electrodes clamped in place. He was thus isolated from all noise and distracting influence. An electric button was near his hand by means of which he could signal to the experimenter and thus regulate the intensity of the stimulus. With care just noticeable stimuli were easily obtained; but no

fluctuations of intensity could be detected, although repeated attempts were made on a number of observers. It hardly seems possible that failure to obtain fluctuations could have been due to faulty conditions.

We submit these results hoping that, when they have been verified elsewhere, they will prove as decisive to others as they have been to us. We trust that in them ample evidence has been afforded that Lange advanced the theory of fluctuation of attention upon insufficient data. Indeed, that an attempt ever should have been made to gather together these discrete sense-phenomena under the head of 'fluctuation of attention' seems more the result of doctrinal development than of a thorough-going consideration of the phenomena themselves.